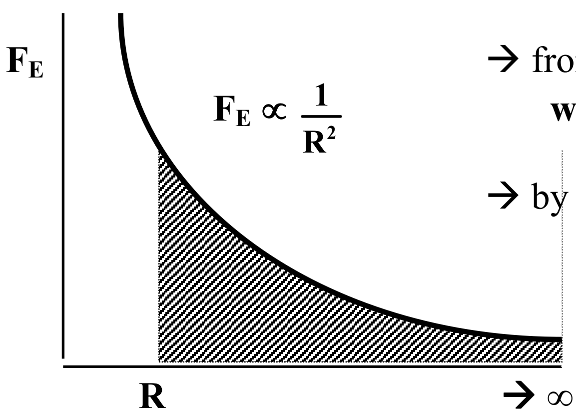
Electric Potential Energy

If two attracting charges were put in an electric field, side by side, and then a force was applied on the negative charge in order to separate them, the work done to do this separation would be the electric potential energy difference (measured in Joules) between the two charges in their new location.

Now suppose that the electron were moved far enough away so that the electrostatic force between both charges becomes weaker and weaker until finally, $\mathbf{F_E = 0}$.

From graphical analysis of electric force $\mathbf{F_E}$ vs. $\mathbf{R}$: (remember that $\mathbf{F_E} = \frac{\mathbf{kQq}}{\mathbf{R^2}}$)



→ from any point **R** out to ∞,
work done = area under the graph

→ by calculus, $\mathbf{W = \frac{kQq}{R}}$

Like gravity, at *infinity* there is no electrostatic force, so potential energy is zero. Therefore, similar to gravitational potential energy:

$$\boxed{\mathbf{E_p = \frac{kQq}{R}}}$$

Some important points about this formula:

- potential energy is a scalar quantity. No vector analysis is required
- for two oppositely charged particles, the potential energy between them is <u>always</u> *negative*. This is because of the *attractive* force between them:
  - ➢ two opposite charges have more potential energy when they are further apart (they can potentially move further *toward* each other).

  - Since the greatest distance apart is at $\mathbf{R} = \infty$ (where $\mathbf{E_p = 0}$), at any separation distance that is smaller, $\mathbf{E_p < 0}$ and must be negative.
- For two similarly charged particles, the potential energy between them is always *positive*. This is because of the *repulsive* force between them:
  - Two similar charges have less potential energy when they are further apart. They attempt to push each other apart to a distance $\mathbf{R} = \infty$, and have less distance to get there (thus, less potential).
  - Since the greatest distance apart is at $\mathbf{R} = \infty$ (where $\mathbf{E_p = 0}$), at any separation distance that is smaller, $\mathbf{E_p > 0}$ (more potential to move apart) and must be positive.

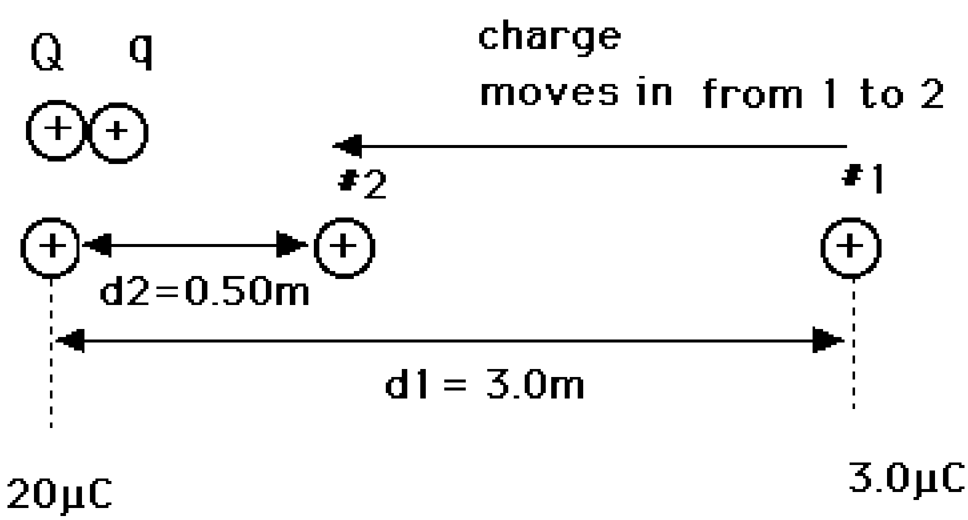
The bottom line is this: use the signs of the charges (+, -) when calculating potential energy $\mathbf{E_p}$. Opposite charges will reveal a negative **Ep**, while like charges will reveal a positive $\mathbf{E_p}$.

Finally, we can determine the work done on the system when one charge is brought in from infinity towards another charge:

→ $\mathbf{W = \Delta E_p = E_2 - E_1}$ ---> but $\mathbf{E_1}$ at infinity $= \mathbf{0}$

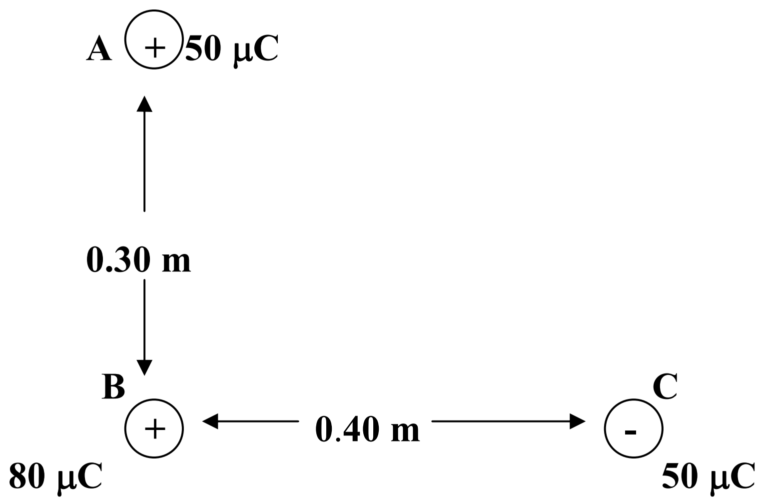
→ $\therefore\ \mathbf{W = E_2 = \dfrac{kQq}{R_2}}$

Example 9. Find the work done to move a charge (q) from position #1 to #2 under the influence of the field of charge Q. (0.90 J)



(see Electrostatics Ex 9 for answer)

Example 10. Re-examine the diagram from Example 4 (see below). Find the potential energy of particle B due to the other charges.



This is somewhat similar to the forces question, but since energy is a *scalar* quantity, you don't use vector diagrams to solve. Instead:

1) find the potential energy between **A** and **B**;
2) find the potential energy between **B** and **C**: (note: in this case you must include the sign of the negative charge)
3) add the two quantities together to find the total potential energy contained in **B**.

(see Electrostatics Ex 10 for answer)